A SECOND ORDER DIFFERENTIAL IMPORTANCE MEASURE FOR RELIABILITY AND RISK APPLICATIONS

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ABSTRACT

A common limitation of the importance measures currently used in reliability and risk analyses is that they rank only individual components or basic events whereas they are not directly applicable to combinations or groups of components or basic events [1]. In practice different basic events may, for example, represent different modes of failure or unavailability of a single component and in order to determine the importance of such component one has to consider all the related basic events as a group. Furthermore, many risk-informed applications deal with evaluating the risk change associated to changes in the plant technical specifications (surveillance and/or test frequencies, etc): such changes may indeed impact a group of components. Recently, the Differential Importance Measure, DIM, has been introduced for use in risk-informed decision making [2]. The DIM is a first-order sensitivity measure that ranks the parameters of the risk model according to the fraction of the total change in the risk that is due to a small change in the parameters' values. The DIM bears an important property of additivity: the DIM of a group of components or basic events is the sum of the DIMs of the single components or basic events of the group. However, since DIM considers risk changes due to small changes of the parameters' values, it does not account for second-order interactions among components.

Importance measures capable of considering combinations of components are needed also when planning a budget-constrained improvement in the reliability of a system design for example by replacing one of its components with a better-performing one, or by inspecting and maintaining it more frequently. Due to the budget constraint, the improvement may need to be accompanied by the sacrifice of the performance of another, less important component. The interactions of these coupled changes to system design must be accounted for when assessing the importance of the system components. To this aim, second order sensitivity measures such as the Joint Reliability Importance (JRI) and the Joint Failure Importance (JFI) measures have been introduced [3, 4].

In this paper, a second-order extension of the DIM, named DIM^{II}, is proposed for accounting of the interactions of pairs of components when evaluating the change in system performance due to changes of the reliability parameters of the components. The extension aims at supplementing the first-order information provided by DIM with the second-order information provided by JRI and JFI.

A numerical application is presented in which the informative contents of DIM and DIM^{II} are compared. The results confirm that in certain cases when second-order interactions among components are accounted for, the importance ranking of the components may differ from those produced by a first-order sensitivity measure. Obviously, the need of resorting to information on second-order effects depends on the magnitude of the changes of the parameters values. It is shown in the paper that in some applications it is possible to determine a priori whether the interaction term in DIM^{II} can be neglected even for large changes in the parameters, thus avoiding the computation of the JRI and JFI measures for all of the possible pairs of components.

References

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